COUPLING OF CFD AND CSM CODES FOR THE STUDY OF PROJECTILE RESPONSE TO BALLISTICS ENVIRONMENT

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ABSTRACT

The state-of-the-art interior ballistics (IB) code for the Army, ARL-NGEN3, is being used to predict the interior ballistics behavior of next-generation gun charges, which include densely-packed solid propellants. Recently, the results from ARL-NGEN3 code simulations were linked to structural dynamics codes in order to predict the in-bore behavior of the projectile afterbody. In the current paper results are presented from recent efforts to bring together the capabilities of ARL-NGEN3 and two of the prominent structural mechanics codes, DYNA3D and EPIC. Results from simulations of a test case show the effectiveness of this approach.

1. INTRODUCTION

An ongoing research effort between the US Army Research Laboratory and the Army High Performance Computing Research Center involves bringing together numerical models with different yet complementary capabilities and using these codes to study complex munitions systems (Newill, et al., 2004). One system of high interest is the smart munitions suite of the Army's Future Combat Systems. Densely packed charges can have poor burning characteristics that cause large pressure waves moving axially around the projectile afterbody. These pressure waves can cause damage to the electronics of a smart projectile. The authors are studying numerical means of predicting the size of pressure waves within the combustion chamber and the response of the projectile to this loading.

2. METHODOLOGY

The current state of the art interior ballistics code is ARL-NGEN3 (Nusca, 2002), and it is used in this work to predict the propellant combustion. ARL-NGEN3 is a multi-dimensional, multi-phase computational fluid dynamics code capable of modeling flamespreading and combustion in advanced direct-fire and indirect-fire gun propulsion systems. The code uses a coupled Lagrangian-Eulerian approach, enabling it to simulate both the continuous component of the flow (gases) and the discrete component (solid propellant). ARL-NGEN3 predicts the propellant combustion and resulting pressure load on the projectile afterbody.

The mechanical response of the afterbody to the pressure load is predicted by two advanced solid mechanics codes, DYNA3D (Whirley, et al., 1993) and EPIC (Johnson, et al., 2003). They are among the foremost computational structural mechanics (CSM) codes available today. They are both finite-element-based Lagrangian hydrocodes, although the codes use different algorithms in some of their features, a notable example being the contact algorithms used by the codes. Both codes are currently being used in this work in order to determine the relative strengths and weaknesses (if any) of the codes in simulating this class of applications.

Presently, the ARL-NGEN3 code is coupled to the CSM codes using a one-way coupling technique. That is, the IB data produced by ARL-NGEN3 is used to drive the CSM simulations while an indication of possible structural deformation and failure, coming from the CSM code, does not affect the IB simulation. Future refinements to this technique are being investigated.

3. RESULTS

The test case involves a notional case telescope ammunition (CTA) projectile with a large afterbody intruding into the combustion chamber. ARL-NGEN3 was used to predict the combustion of the granular JA2 propellant initially placed around and behind the projectile afterbody. There were initially small amounts of M1 and black powder at the breech end of the chamber for igniting the charge. Figure 1 shows the color pressure contours (blue to red: 0 to 85 kpsi) and velocity vectors at 2.4 ms into the dynamic simulation. Figure 2 shows the computed pressure-time data on the chamber wall at the points labeled "R", "M", and "F" in Figure 1. The double

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peaks of the curves in Figure 2 combined with the magnitude of the peak pressure indicate that there are large pressure waves moving longitudinally during the firing cycle.

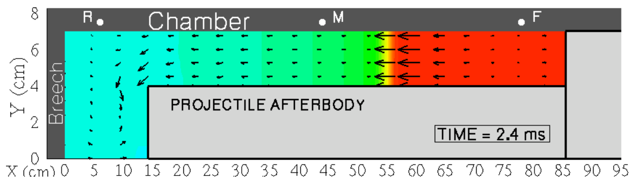

Figure 1. Pressure contours and velocity vectors at 2.4 ms predicted by the ARL-NGEN3 code.

Such waves pose a challenge for the design of the projectile. Determining the structural response of the projectile tail to these waves aids in the design process. The notional CTA projectile was given the front end shown in Figure 3. The resulting projectile is not used in any ammunition of current interest, but its use should point to and allow the study of issues facing other deeply intruding projectiles.

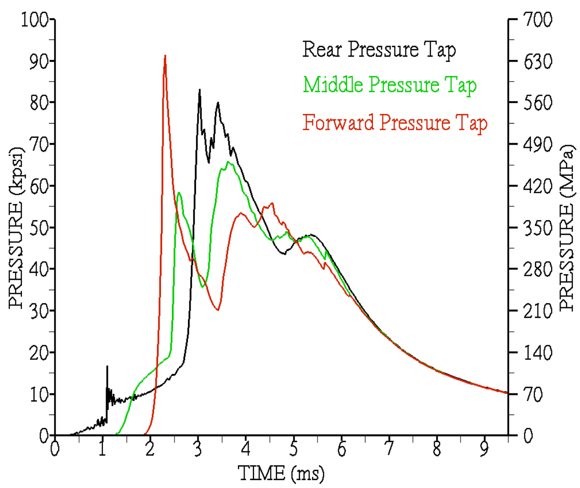

Figure 2. Pressure-time data computed by ARL-NGEN3 at three points in the combustion chamber.

Figure 3 shows the equivalent stress in the projectile at 2.4 ms into the dynamic simulation using the DYNA3D and EPIC codes. The meshes used by the codes are not identical, but they do have comparable element sizes. The large red regions (i.e., 90 ksi) show that both codes predict that the projectile, if made of typical materials and having a reasonable amount of cargo space, would fail under this pressure loading. These results and others not included here indicate that the data from the CSM codes agree quite well. Further comparisons will be made.

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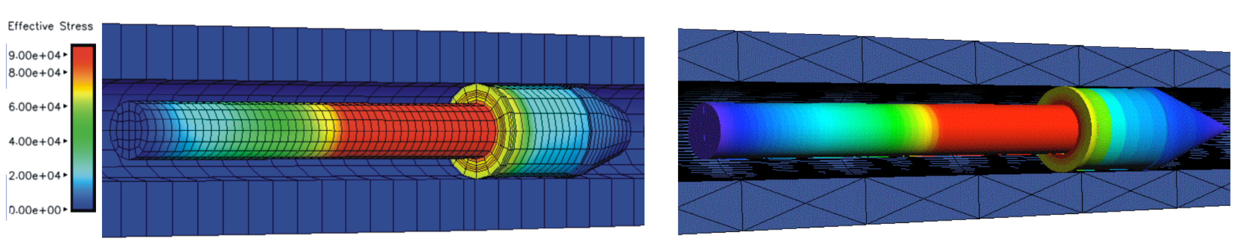

Figure 3. Equivalent strain in the projectile at 2.4 ms, DYNA3D (left), EPIC (right).